Proc. Assoc. Advmt. Breed. Genet. 21: 33-36

ACCOUNTING FOR THE COST OF REPRODUCTIVE TECHNOLOGIES DURING SELECTION IN SHEEP BREEDING PROGRAMS

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SUMMARY

Female reproductive technologies, such as MOET and JIVET, have been shown to increase the rate of genetic gain. However, they incur substantial costs to breeders using them. In this work, optimal contribution selection was used to find the balance between genetic merit, co-ancestry and cost of reproductive technologies in sheep breeding programs. To offset the cost of using the reproductive technologies, breeders received a premium based on the value of the genetic gain achieved by the ram buyers. Australian terminal sire and Merino breeding programs were simulated, using industry indexes. For the terminal sire breeding program, the premium needed to be greater than 50% before reproductive technologies were used. In the Merino breeding program, where the standard deviation of the index is 3 times higher than the terminal index, reproductive technologies were used with lower premiums (6% and 32% premiums, respectively). For both breeding programs, the rate of genetic gain increased with more allocations of reproductive technologies. There was also a higher proportion of JIVET assigned compared to MOET, due to a lower cost per lamb. The benefits of genomic selection were greatest in the merino program, due to the higher use of JIVET. Assigning costs of reproductive technologies allows for robust and practical breeding programs to be designed.

INTRODUCTION

Female reproductive technologies such as multiple ovulation and embryo transfer (MOET) and juvenile *in vitro* fertilisation and embryo transfer (JIVET) have been shown to increase rates of genetic gain by increasing selection intensity and decreasing generation interval. However, use of these reproductive technologies can result in higher rates of inbreeding through selection emphasis on elite families rather than elite individuals within families. JIVET has become a more viable reproductive technology option since the introduction of genomic testing as it increases the selection accuracy of juvenile animals. Optimal contribution selection (Wray and Goddard 1994) is an effective selection tool to maximise genetic gain while maintaining sustainable rates of inbreeding. It has been shown to be an effective method in optimising allocation of reproductive technologies in stochastic simulations where long-term genetic merit and co-ancestry are balanced, and could also be used to account for the cost of reproductive technologies. To warrant breeders investing in expensive genetic acceleration programs using reproductive technologies, a premium per ram should be paid by ram buyer which reflects the proportion of total benefits of increased genetic gain that flows to the buyer.

This paper aims to explore, via a stochastic simulation study, the optimal allocation of reproductive technologies using optimal contribution selection and accounting for the cost of reproductive technologies.

MATERIALS AND METHODS

We evaluated reproductive technologies in both terminal sire and Merino breeding programs, with selection based on industry indexes ("Lamb 2020" for terminal sires and "Merino Production" for Merinos, from http://www.sheepgenetics.org.au). A closed breeding nucleus of 250 sheep were stochastically simulated and then bred over 15 years over 100 replications. For each scenario an unrelated base population and subsequent overlapping generations were generated. True breeding values and phenotypes were simulated with variances and co-variances used in the Sheep Genetics evaluation system (Huisman et al. 2008). Each year individual animals had breeding values estimated (EBV) via pedigree based on multi-trait Best Linear Unbiased Prediction (BLUP) using ASReml software (Gilmour et al. 2009).

There were up to three types of matings allowed in the breeding programs: 1) artificial insemination or natural mating (AI/N) 2) MOET and 3) JIVET. Individuals were selected for one of these mating types using optimal contribution selection (Wray and Goddard 1994). The objective function M+C-R was optimised, where M=x'b where x is a vector with genetic contributions and b is a vector with BLUP EBV on n selection candidates; $C=\lambda \cdot x'Ax$ where λ is a negative value to maintain inbreeding rate at 1% (±0.05) per generation, and A is the pedigree relationship matrix among selection candidates; $R = \beta \cdot x'd_t$ where d_t is cost per lamb resultant from reproductive technology (t) (Table 4). β is a scaling factor to express the cost of using reproductive technologies on the same scale as the additional genetic merit of the animals selected. Hence, $\beta= W_2/(p \cdot W_1)$ where W_2 is the number of progeny born in the nucleus each year multiplied by 2, W_1 is the number of commercial animals bred by rams from nucleus multiplied by the cumulative discount expression (CDE) of genetic superiority (Hill 1974) and p is a premium paid by ram buyers which is the equivalent to a proportion of the genetic benefit (resultant change in index) they will receive in their commercial flock(s) of 5000 ewes and paid back to the ram breeder. The premiums paid (p) varied at levels of 0.06, 0.32 and 0.64 as representations of low, medium and high premiums. The cost of reproductive technology and average number of lambs born per technology are shown in Table 1. Costs included drugs, professional services and price of failed transfers. The fecundity was averaged from previous studies and costs averaged from questionnaires completed by advanced reproduction companies in Australia.

For each breeding program and index the impact of genomic selection (GS), assuming all animals had genomic information available at birth, was assessed. The cost of GS was not accounted for in this study. Genomic information was modeled following the method of Dekkers (2007) which simulates a genomic breeding value as a correlated trait with a heritability of 0.999 and a correlation *r* to the measured trait, where *r* is the accuracy of the genomic breeding value for each trait. The accuracy of the genomic test varied for each trait (Swan *et al.* 2014).

Table 1. **Average cost per lamb and number of progeny per program.**

Technology	Cost ($/lamb)	Ave. progeny (n)
No mating	0	0
AI/N	20	1
MOET	160	4
JIVET	130	8

RESULTS AND DISCUSSION

In the terminal sire breeding programs, the proportion of benefit paid to the breeder had to reach 0.64 before any reproductive technologies were assigned. At a premium of 0.64 for the terminal breeding program, it was observed an increase in annual response in the nucleus of 5% was associated with 3-5% of lambs born via JIVET technology (Table 2). By contrast, the Merino breeding programs had reproductive technologies assigned when the proportion of benefit was as low as 0.06 (Table 2). This is expected with the Merino index having a larger index dollar genetic standard deviation and therefore a higher value of the genetic gain achieved. In the Merino index it was observed that as the premium increased, the allocation of reproductive technologies increased, as did the genetic gain (Table 2). In the AI/N+ MOET+JIVET program (using GS) a 75% higher rate of genetic gain was observed for the 0.64 premium scenario compared to the 0.06 premium scenario.

Table 2. Proportion of lambs born to reproductive technologies, number of dams required to breed 250 lambs, annual genetic gain (G/yr) and average generation interval (L) in respective breeding programs using terminal sire Lamb 2020 and Merino MP indexes at 1% increase in inbreeding per generation.

Proportion of benefit paid to breeder	AI	MOET	JIVET	Dams Used	G/yr ($)	L
Lamb 2020						
AI/N + MOET + JIVET (GS)						
0.06	1.00	0.00	0.00	271	1.24	1.83
0.32	1.00	0.00	0.00	268	1.28	1.86
0.64	0.95	0.00	0.05	259	1.31	1.81
AI/N + MOET + JIVET						
0.06	1.00	0.00	0.00	269	1.13	1.94
0.32	1.00	0.00	0.00	273	1.18	1.98
0.64	0.97	0.00	0.03	268	1.19	1.91
MP						
AI/N + MOET + JIVET (GS)						
0.06	0.95	0.00	0.05	261	2.26	1.87
0.32	0.77	0.04	0.19	221	2.82	1.46
0.64	0.36	0.10	0.54	136	3.96	1.21
AI/N + MOET + JIVET						
0.06	0.94	0.01	0.05	268	1.32	1.98
0.32	0.82	0.03	0.15	233	1.85	1.51
0.64	0.41	0.12	0.47	129	2.02	1.38

SEM for dams used ≤±4.3, ΔG/yr ≤±$0.05, L ≤± 0.05 for all breeding programs.

The impact of using genomic selection in breeding programs varied between indexes. For terminal breeding programs, when comparing the same breeding program with and without genomic selection, a 6-10% increase in annual response was found (Table 2). This low increase is expected with the key traits measured within 6 months of life and very little JIVET assigned, where genomic selection would be most beneficial in a terminal breeding program. However, we observed increases of up to 96% in the Merino breeding program. The larger response with genomic selection is expected with all traits measured after one year of age and key traits, such as number lambs weaned, not phenotypically measured.

In both Merino and Terminal breeding programs where only up to 5% of progeny resulting from JIVET, slight increases in annual genetic gain of up to 7% were found (Table 2). It is expected that these matings are performed on females that are outliers in the population and would produce progeny that significantly contribute to subsequent generations (i.e. ram progeny selected in future years). These matings are strategic and may be observed in current breeding practices in industry.

When the cost of reproductive technology is accounted for during selection and the premium paid by buyers is zero, the extra income received through higher performance (i.e. increased fleece weight, etc.) facilitated via genetic gain is not high enough to justify its use. Therefore, ram buyers who want genetically superior rams derived from the use of advanced reproductive technologies, will need to pay some form of premium to the ram breeders. However, past experience has shown that the value of premiums paid by ram buyers can be somewhat arbitrary and usually follow market trends rather than benefit captured by the buyers (Banks *et al.* 2014).

CONCLUSIONS

Applying a true cost to reproductive technologies during the optimal contribution selection method delivered practical mating solutions in breeding programs. A premium paid as a proportion of the benefit received by ram buyers for stud rams provides an avenue to justify and recover the costs of using reproductive technologies by stud breeders. Higher premiums paid resulted in more reproductive technologies used and as consequence, faster annual rates of genetic gain. Genomic selection facilitated better selection decisions on younger selection candidates and provided the most benefit in the Merino breeding programs, where most traits in the index are measured later in life, not measured at all, or are hard to measure. A terminal sire program using the Lamb 2020 index had limited justification for investment in reproductive technologies to accelerate genetic gain due to comparatively low rates of true dollar genetic gain.

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